Free-stream turbulence generation at low Reynolds number: a comparison between synthetic and grid-induced turbulence

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Unsteady aerodynamics at relatively low Reynolds number (i.e., $Re \sim 10^2 - 10^4$) concerns problems attracting considerable scientific and technological interest, such as the design of micro-aerial vehicles or small scale energy harvesting. For these applications, the flow perturbations and/or turbulence of the atmospheric boundary layer can have a dramatic effect on the aerodynamic performance. In this work, we aim at developing and testing suitable strategies to obtain free-stream perturbations with well-defined and controllable properties (e.g., intensity, homogeneity, isotropy, and scale-by-scale energy distribution) in the framework of high-fidelity, direct numerical simulations (DNS). Seeking for a realistic yet general configuration, we consider two distinct and complementary approaches that can be used to obtain a perturbed or turbulent inflow. The first is a synthetic turbulence inflow generator (STIG), considering the implementation based on digital filters[1,2] and, in particular, using a source term forcing[3]. The fluctuations generated by the STIG are characterized by their turbulent intensity TI_0 and an integral lengthscale Λ_0, which represents a convenient feature of this approach. In the second approach we simulate grid-induced turbulence (GT), using an immersed boundary method and placing a passive solid grid with a specific geometry after the inlet[4]; such a fully resolved approach ensures a physically-based generation of the flow perturbations. The comparative analysis of STIG and GT results will include the decay of turbulent kinetic energy, spectral energy distribution and evolution of the characteristic spatio-temporal scales.

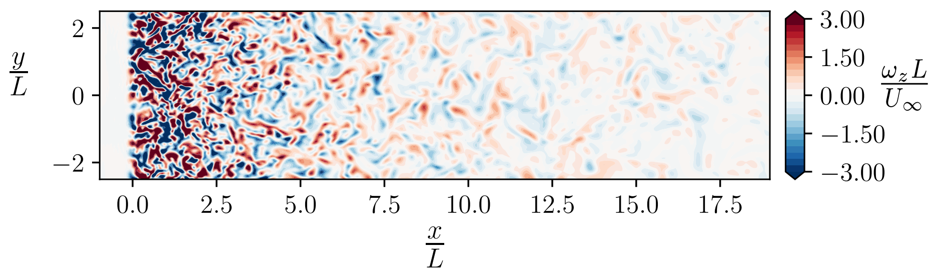

Figure 1: Instantaneous (out-of-plane) z-component of the vorticity field in the longitudinal midplane at $z/L = 0$ from DNS performed using the STIG approach.

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[1] Klein et al., *J. Comput. Phys.* **186**, 652 (2003).
[2] Kempf et al., *Comput. Fluids* **60**, 58 (2012).
[3] Schmidt and Breuer, *Comput. Fluids* **146**, 1 (2017).
[4] Olivieri et al., *Phys. Fluids* **34**, 085116 (2021).